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CHAPTER 5.2

OTHER CASTINGS

B. W. Niebel

*Professor Emeritus of Industrial Engineering
The Pennsylvania State University
University Park, Pennsylvania*

PERMANENT-MOLD CASTINGS

The Process

Permanent-mold casting makes use of reusable metal molds that are filled with metal by gravity as in sand-mold casting. Cores of metal or sand may be used. Molds are generally made of cast iron and frequently have a thick [up to 0.75-mm (0.030-in)] coating of sodium silicate and clay or other insulating materials over the cast-iron surface.

Permanent molds are preheated to 150 to 200°C before pouring and are given a graphite dusting every three or four shots. Thermal balance is very important, and auxiliary water cooling or radiation pins are used to cool heavy sections. Proper venting of the cavity is very important in order to avoid misruns. The process is illustrated by Fig. 5.2.1.

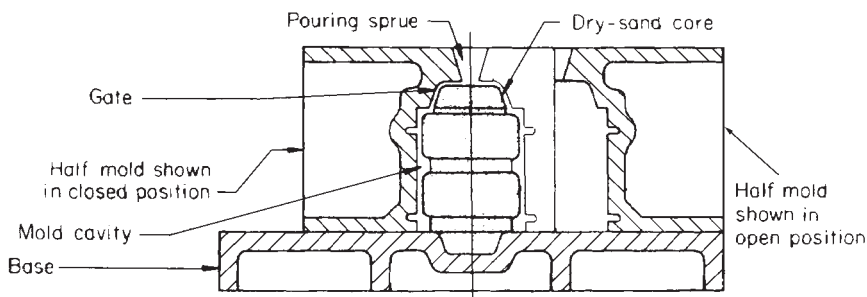


FIGURE 5.2.1 Permanent-mold casting. (Courtesy General Motors Engineering Standards.)

Low-Pressure Permanent-Mold Casting

In this type of casting, the liquid metal (usually aluminum) is forced by low air pressure from a silicon carbide crucible into the die cavity. If a proper heat balance is maintained, risers are eliminated and there is a high casting yield.

Typical Characteristics and Applications

The permanent-mold casting process is especially applicable for producing small- and medium-sized components of aluminum-base, magnesium-base, and bronze alloys. Seldom do permanent-mold castings weigh 100 kg (220 lb) or more.

Metal-mold castings have some distinct advantages over typical sand-mold castings. These include closer dimensional tolerances, better surface finish, greater strength, and more economical production in larger quantities. Disadvantages are the possibility of hot tearing, which results from the inability of the metallic mold to accommodate the contraction forces of the solidifying metal, and difficulty in removing the casting from the mold because the mold cannot be broken up. For these and other reasons, permanent-mold castings are apt to be relatively simple in shape, less intricate than many die castings. The ceramic-mold coating may cause a somewhat poorer casting surface finish and wider tolerance than are found in a typical aluminum or zinc-base die casting. Permanent-mold castings are superior to die castings from the standpoint of strength, density, pressure tightness, and mold cost. Improved density is the reason that automotive pistons are cast in permanent molds rather than die-cast.

Typical permanent-mold castings include gears, splines, hydraulic cylinders, motor parts, bushings, air-cooled cylinder heads, wheels, gear housings, washing-machine agitators, pipe fittings, and the like. Figure 5.2.2 illustrates a fuel-injector body produced by permanent-mold casting.

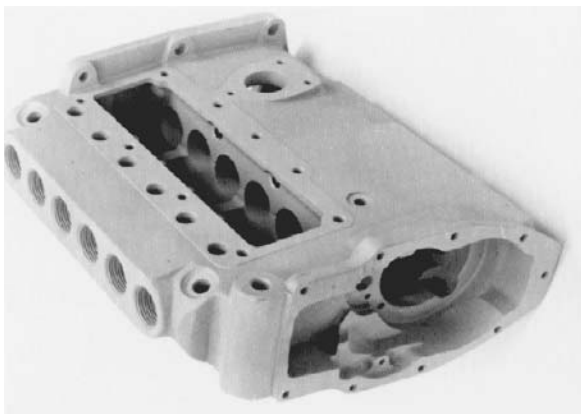


FIGURE 5.2.2 Fuel-injector body produced by the permanent-mold casting process. (Courtesy Oberdorfer Foundries, Inc.)

Economic Production Quantities

Both low-pressure permanent molding and permanent molding represent competitive methods of manufacture for quantities up to approximately 40,000 pieces. Molds for permanent-mold castings are more expensive than patterns for sand-mold castings but less costly than die-casting dies. The labor content of a typical permanent-mold casting, on the other hand, is less than that of an equivalent sand-mold casting but higher than that of an equivalent die casting.

Figure 5.2.3 illustrates the relative cost of various casting methods for various quantities of one particular part. Note that the break-even point for permanent-mold castings when compared with die castings is approximately 20,000 pieces. The break-even point of low-pressure permanent-mold castings when compared with die castings is larger.

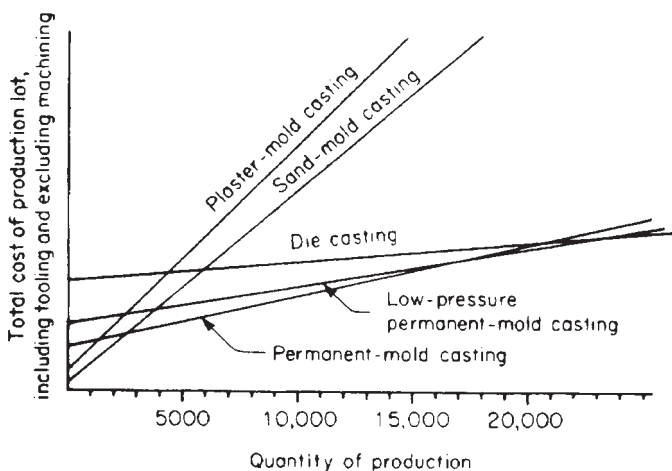


FIGURE 5.2.3 Relative cost of different casting process for one particular aluminum alloy part at various production levels.

Quantities in the range of 2500 pieces or more allow the process to compete with sand casting. High rates of production are possible when multiple-cavity dies are used. Die life is relatively long, being up to 50,000 parts per cavity when casting small gray-iron parts if protected with ceramics and considerably more in connection with the casting of nonferrous alloys. Quantities of 100,000 parts per cavity are not unusual when casting magnesium.

Suitable Materials

Permanent-mold casting can be used to produce components of aluminum, magnesium, copper-base alloys, and gray iron. Its widest application has been in connection with aluminum alloys. See Table 5.2.1 for a summary of suitable aluminum alloys.

In magnesium, alloys AZ91E (M11918), AZ63A (M11630), and AZ92A (M11920)

TABLE 5.2.1 Common Aluminum Alloys for Permanent-Mold Casting

Aluminum Association designation	UNS designation	Fluidity	Shrinkage tendency	Resistance to hot cracking	Pressure tightness	Machinability	Corrosion resistance	Weldability
359.0	A03590	A	A	A	A	C	B	A
356.0	A03560	A	A	A	A	C	B	B
357.0	A03570	A	A	A	A	C	B	B
443.0	A04430	B	A	A	A	E	B	A
332.0	A03320	A	B	A	B	D	C	B
213.0	A02130	B	C	C	C	B	D	B
771.0	A07710	C	C	D	D	A	B	—
201.0	A02010	C	D	D	C	A	D	B
711.0	A07110	E	D	E	D	A	C	C
240.0	A02400	C	D	D	D	C	D	D

Source: Data from the Aluminum Association.

are commonly used. For copper-base alloys, aluminum bronze 89-1-10 (C95300) is a good choice.

Design Recommendations

Castings to be produced by permanent-mold methods should be simple in design with fairly uniform wall sections and without undercuts and complicated coring. If a specific design requires undercuts or relatively complicated coring, semipermanent molds should be considered. Here sand cores are used with the metal mold.

Holes. Holes are best kept in the direction of parting of the mold halves so that separate core pieces are not required. (See Fig. 5.2.4.) Note also that the minimum diameter of cored holes is 6 to 9 mm (0.25 to 0.35 in), depending on the hole depth. The greater the hole depth, the greater the minimum diameter of the core. The hole depth should not be greater than six diameters; otherwise, cores will not be sufficiently rigid.

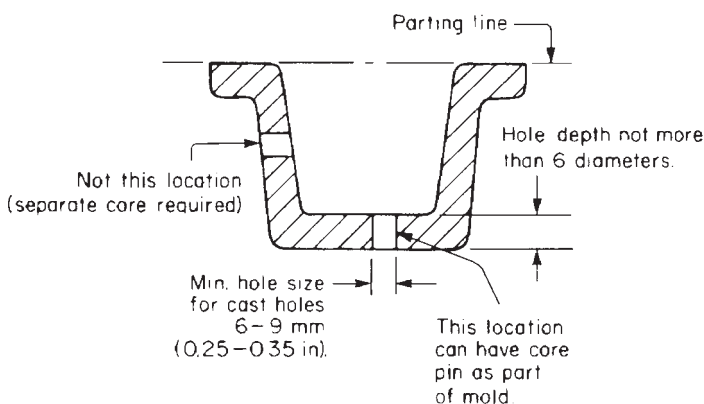


FIGURE 5.2.4 Rules for cored holes.

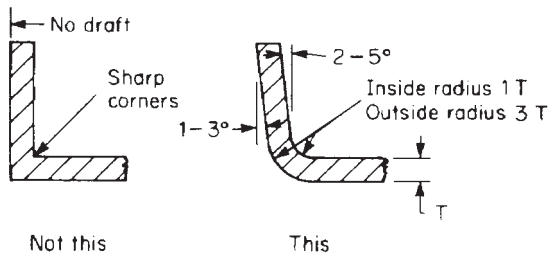
Draft. Draft is required on the walls of permanent-mold castings to permit easy withdrawal of the casting from the mold. More draft is required on inside sections, since the metal shrinks away from the mold surface but tightens around cores during solidification. The recommended minimum draft for exterior surfaces is 1 to 3° and for interior surfaces is 2 to 5° with greater draft angles being required for lower walls. (See Table 5.2.2.)

Fillets and Radii. Permanent-mold castings should be designed with generous fillets and radii to facilitate metal flow, promote more uniform cooling, and prevent stress concentrations. Fillets should have a radius at least equal to one wall thickness, while outer radii should be 3 times wall thickness. (See Fig. 5.2.5.)

Wall Thickness. The minimum wall thickness of permanent-mold castings is approximately 3 mm ($\frac{1}{8}$ in), and this stricture applies to small castings. Table 5.2.2 lists average minimum values for a range of casting sizes.

TABLE 5.2.2 Recommended Dimensions for Permanent-Mold Castings

Minimum wall thickness					
Casting size	Under 75 mm (3 in)		75–150 mm (3–6 in)	Over 150 mm (6 in)	
Minimum wall thickness	3 mm ($\frac{1}{8}$ in)		4 mm ($\frac{5}{32}$ in)	5 mm ($\frac{3}{16}$ in)	
Corner radii					
Inside radius = t (t = average wall thickness)					
Outside radius = $3t$ (blend tangent to walls)					
Draft angles					
	Outside surfaces	Inside surfaces	Short cores	Average cores	Recesses
Minimum angle	1°	2°	2°	2°	2°
Preferable angle	3°	5°	3°	3°	5°
Machining allowances					
Casting size	Under 250 mm (10 in)		Over 250 mm (10 in)	Sand-core surfaces	
Minimum allowance	0.8 mm ($\frac{1}{32}$ in)		1.2 mm ($\frac{3}{64}$ in)	1.5 mm ($\frac{1}{16}$ in)	
Preferred allowance	1.2 mm ($\frac{3}{64}$ in)		1.5 mm ($\frac{1}{16}$ in)	2.0 mm ($\frac{5}{64}$ in)	

**FIGURE 5.2.5** Avoid sharp corners in permanent-mold castings.

Ribs. Ribs for permanent-mold castings should follow the guidelines outlined in Chap. 5.1 for sand-mold castings.

Inserts. Inserts of metals other than the casting metal can be incorporated readily in permanent-mold castings. Normally some locking features—grooves, knurls, slots, holes, or lugs—are required to ensure that the insert is secured in the casting. Full wall thickness should be provided around the inserts to avoid overstressing the casting.

Markings. Lettering and other identifying markings can be cast into permanent-mold castings with no additional cost except that required in constructing the mold. Design recommendations for markings in die castings (Chap. 5.4) apply to permanent-

mold castings as well.

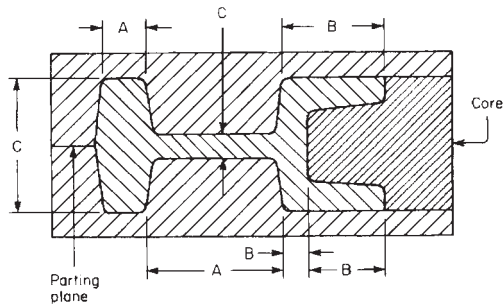
Parting Line. As in the case of sand-mold and other castings, a flat parting surface between mold halves is preferable. The casting should be designed to permit this and to have a convenient parting-plane location.

Variations in Wall Thickness. These cause casting problems and workpiece inaccuracies because of uneven cooling. If section changes are unavoidable, however, the transition from a heavy to a thin section should be as gradual as possible.

Machining Allowances. Although permanent-mold castings are more accurate than sand-mold castings, there are still many instances in which they must be machined before castings are ready for functional use. The amount of material added to permanent-mold castings for machining is less than that required for sand-mold castings. Normal allowances, summarized in Table 5.2.2, range from 0.8 mm ($\frac{1}{32}$ in) to 2 mm ($\frac{5}{64}$ in).

Recommended Tolerances

Figure 5.2.6 presents typical dimensional tolerances for average permanent-mold castings.



	For dimensions up to 25 mm (1 in)	Additional tolerances for dimensions over 25 mm (1 in)
Dimensions produced by one mold half (A)	$\pm 0.4 \text{ mm } (\pm 0.015 \text{ in})$	$\pm 0.1 \text{ mm/100 mm } (\pm 0.001 \text{ in/in})^*$
Dimensions between points produced by a core and the mold (B) or across parting plane (C)	$\pm 0.5 \text{ mm } (\pm 0.020 \text{ in})$	$\pm 0.2 \text{ mm/100 mm } (\pm 0.002 \text{ in/in})^*$
*For copper alloys, allow 0.5 mm/100 mm (0.005 in/in) additional.		
Surface finish		
Low-pressure process	0.5–3.2 μm (20–125 μin)	
Conventional process	3.8–13 μm (150–500 μin)	

FIGURE 5.2.6 Recommended tolerances for permanent-mold castings.

CENTRIFUGAL CASTINGS

The Process

Centrifugal casting is a specialized casting process that provides a cost-effective method for producing hollow cylindrical parts and circular plates as well as intricate parts. The most common centrifugal process, true centrifugal casting, is used for pipe liners, steel tubing, and other hollow, symmetrical objects. It involves the use of centrifugal force to hold the metal against the outer walls of the rotating tubular mold while the volume of metal poured determines the wall thickness and internal diameter. No core is used, and the inner surface tends to collect the lighter dross and impurities.

Molds are divided into two classes, permanent and lined. In the lined mold, a flask with a baked or green-sand lining is placed horizontally on a casting machine, where it is rotated by a system of rollers actuated by an electric motor. Molten metal is fed into one end of the mold cavity and is carried to the walls of the cavity by centrifugal force. Rotative speeds sufficient to produce a force of up to 150 times the force of gravity are feasible. High forces are necessary for casting exceptionally thick walls.

Permanent molds are made of steel, iron, or graphite. Graphite molds are used principally in the casting of titanium. Usually, a thin refractory wash is sprayed on the inside surface to increase mold life and permit faster solidification.

Horizontal molds are generally used to cast long cylinders and pipes, whereas vertically spinning molds are generally used in the production of short castings of variable diameters and different shapes.

In one process variation, semicentrifugal casting, the process is used for forming

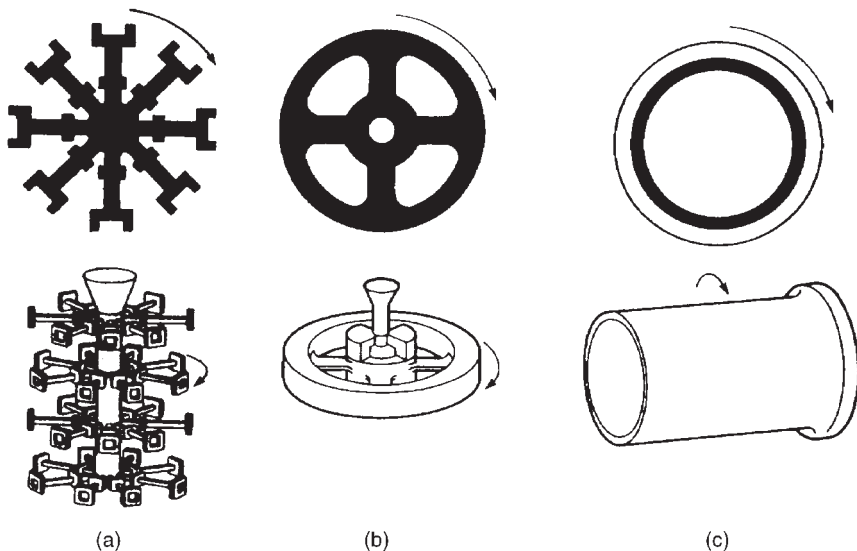


FIGURE 5.2.7 Three types of centrifugal castings are: (a) centrifuging; (b) semicentrifugal; (c) true centrifugal. (From David C. Ekey and Wesley P. Winter, *Introduction to Foundry Technology*, McGraw-Hill, New York, 1958.)

symmetrical shapes such as wheels, nozzles, and similar parts about the rotative vertical axis. The molten metal is introduced through a gate, which is placed on the axis, and flows outward to the extremities of the mold cavity.

In centrifuging, several molds are located radially about a central riser or sprue, and the entire mold is rotated, with the central sprue acting as the axis of rotation. Centrifugal force provides a means for obtaining greater pouring pressures at every point within the mold cavity. This type of centrifugal casting is best used for small, intricate parts where feeding problems might otherwise be encountered.

These three varieties of centrifugal casting are illustrated in Fig. 5.2.7.

Typical Applications

Even though cylinders as small as 13 mm ($\frac{1}{2}$ in) in diameter can be centrifugally cast, from an economic standpoint, 125 mm (5 in) is considered about the minimum diameter. Cylinders up to 3 m (10 ft) in outside diameter with lengths up to 16 m (52 ft) have been cast successfully by centrifugal methods. Typical centrifugal castings include large rolls, gas and water pipe, engine-cylinder liners, wheels, nozzles, bushings, sheaves, gears, ship-shaft liners, bearing rings, and flanged shapes, as well as more intricately shaped components.

Economic Production Quantities

Centrifugal-casting methods have application for very small quantities (down to one), for which sand is used as the mold material, up to large production quantities. Graphite molds are used for small or medium-sized runs. Usually, at least 50 pieces are required to justify a graphite mold. With medium to large runs, it is usually most economical to use a metal mold. Here 400 pieces is representative of the typical break-even point.

Design Considerations

As compared with permanent-mold and sand casting, for which a liberal amount of gating and risering is required, the filling of the mold in all types of centrifugal casting is enhanced by the centrifugal force in back of the metal. There are no gates in true centrifugal castings, and fewer, relatively shorter nubs are needed for centrifugal castings than for typical sand-mold castings. Although the need for radii at adjoining flanges and other design features is not as pronounced as in sand castings, a radius should always be specified so as to avoid stress concentrations.

True centrifugal castings may be cast with a range of wall thickness of 6 to 125 mm ($\frac{1}{4}$ to 5 in). Usually a wall thickness of at least 9 mm (0.35 in) is preferred. The minimum size of cored holes or cored control bores is 25 mm (1 in). If smaller holes are desired, they should be drilled after casting.

Sand molds for true centrifugal castings do not require draft, but draft should be applied for centrifuged parts in accordance with usual sand-casting practice. When using cast-iron molds, draft is applied. As the diameter decreases, the amount of draft needed increases.

TABLE 5.2.3 Typical Tolerances for Centrifugal Castings

Metal molds	Tolerances	
	Normal tolerance, $\pm$	Minimum tolerance, $\pm$
Dimensions to 13 mm ($\frac{1}{2}$ in)	0.5 mm (0.020 in)	0.13 mm (0.005 in)
Dimensions over 13 mm to 130 mm = $(\frac{1}{2}$ in to 5 in)	0.5 mm (0.020 in)	0.25 mm (0.010 in)
Dimensions over 130 mm (5 in)	0.5 mm (0.020 in)	0.38 mm (0.015 in)
Sand molds	Normally ± 0.8 mm (0.030 in) for dimensions to 80 mm (3 in); for values for larger dimensions, see Table 5.1.6.	
Internal diameters	(Determined by centrifugal force) ± 1.5 mm ($\frac{1}{16}$ in)	
Surface finish		
Metal molds	2.5–13 μm (100–500 μin)	
Sand-faced molds	6.3–25 μm (250–1000 μin)	

Suitable Materials

In general, any alloys that can be cast in sand molds can be centrifugally cast. Those metals which are cast regularly on a production basis include carbon steels, alloy steels, brasses, bronzes, aluminum alloys, nickel alloys, cast iron, and copper.

Those alloys having short freezing ranges are particularly desirable for centrifugal casting. Usually, high-phosphorus alloys should be avoided because this element results in a “wetting” characteristic and subsequent removal from the mold is difficult. Also to be avoided are high-lead alloys, which tend to separate.

Recommended Tolerances

Castings produced by any of the three centrifugal methods have tolerances typical of those experienced in sand casting. Table 5.2.3 lists the tolerances that should be readily maintained by the process.

Centrifugal castings made in metal molds will have surface finishes ranging from 4.4 to 6.3 μm (175 to 250 μin). The surface roughness of parts formed against sand will typically range from 12 to 20 μm (300 to 500 μin).

PLASTER-MOLD CASTINGS

Plaster-mold casting is very similar to sand-mold casting except that the mold and cores are made of plaster (or a combination of plaster and sand) instead of packed sand. The mold is usually made in a wood or metal frame containing the pattern. After the plaster sets, the frame and pattern are removed, and the mold halves and cores, if any, are assembled and are normally baked to remove moisture and improve permeability. A new mold is required for each casting as in sand-mold casting. In practice, the mold is poured hot, and a vacuum system continually removes the water vapors produced from the loss of water of hydration. Figure 5.2.8 shows a plaster mold after pouring.

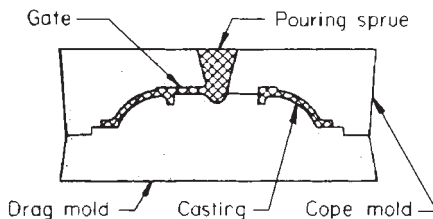


FIGURE 5.2.8 Plaster mold after pouring.
(Courtesy General Motors Engineering Standards.)

Typical Characteristics

The process is useful for producing small nonferrous parts. It permits the production of smooth surfaces, fine detail, thin sections, and dimensionally accurate geometries in the as-cast condition.

Because of their excellent surface finish and good dimensional accuracy, components frequently can be produced to requirements without secondary machining and finishing operations. Plaster molds permit accurate control of shrinkage, distortion or warpage being negligible.

Generally, the surfaces of plaster-mold castings have a satin texture. However, the special surface textures of the pattern can be reproduced in the mold. Plaster-mold castings can be plated easily without special preparation. Surfaces are easily polished and buffed. Castings weighing more than 10 kg are seldom made, although some as large as 100 kg have been cast. The typical casting weighs about 125 to 250 g. Castings as small as 1 g have been made. Typical parts produced include valves, fittings, clutches, sprockets, compressor wheels, gears, impellers, lock components, pistons, cylinder heads, etc.

Economic Production Quantities

The process is relatively high in cost because of the long time required for the plaster to set and the fact that the production rate is low. Also, molds must be poured hot and over a vacuum to remove water vapors. Cooling time is long because plaster is a good insulator. Thus, the cycle time is long.

Either small or large quantities can be run economically by placing the pattern in the line when the proper metal is being poured. One pattern typically can produce 150 to 250 pieces per week. Multiple patterns or plates will increase production accordingly.

The cost of the patterns and core boxes employed in the plaster-mold process is approximately 50 percent higher than the corresponding equipment used in sand casting.

General Design Considerations

Principal design considerations for plaster-mold castings include the following:

1. Keep overall dimensions as small as possible. The process is most suitable for small parts. Mold and materials economies result when castings are small.

2. Keep sections as thin as possible (see limits below), with due regard for strength, stiffness, and allowance for machining.
3. Endeavor to keep sections uniform unless differences are essential to meet service requirements. If sections cannot be uniform, make variations in thickness as gradual as conditions permit.
4. Use cores when savings in metal or machining can be effected or to promote sounder castings. However, avoid slender or fragile cores and those not readily supported by the mold.
5. Avoid undercuts that will prevent removal of the pattern from the mold.
6. Design castings to minimize secondary operations.
7. Employ fillets and rounded corners to strengthen the casting and make it easier to remove the pattern from the mold.

Suitable Materials

Aluminum alloys, zinc alloys, yellow brass, aluminum bronze, manganese bronze, silicon-aluminum bronze, nickel brass, and other bronze alloys with less than 1.5 percent lead all can be cast in plaster molds. The material of the mold can stand a maximum pouring temperature of about 1200°C (2200°F). Consequently, ferrous metals and others with melting points greater than 1100°C (2000°F) cannot be cast. Magnesium is not suitable for plaster casting because of potential chemical reactions between the molten magnesium and the mold or any water remaining in it.

Aluminum alloys form the bulk of plaster-cast parts. Alloys 355.0 (A03550), 356.0 (A03560), 357.0 (A03570), and 443.0 (A04430) are suitable to the process.

Detailed Design Recommendations

Wall Thickness. Although plaster-mold casting can produce thin and sound walls, the following minimum wall thicknesses for given areas should be observed when designing castings:

Walls with projecting areas up to 650 mm² (1 in²): 1-mm (0.040-in) minimum thickness

Walls with projected areas above 650 mm² to 1950 mm² (1 to 3 in²): 1.5-mm (0.060-in) minimum thickness

Walls with projected areas above 1950 mm² to 9750 mm² (3 to 15 in²): 2.4-mm (0.090-in) minimum thickness

Inserts. Inserts can be used with plaster-mold castings. Due regard should be given to potential corrosion problems, and steps must be taken to locate the insert properly in the mold. Fastening methods as described above under “Permanent-Mold Castings” also apply to plaster-mold castings.

Markings. These can easily be incorporated in plaster-mold castings and are clearly reproduced. Lettering should be depressed in the casting rather than raised for mini-

imum cost and, as in other types of castings, should be on a surface parallel to the mold-parting plane for easy pattern removal.

Draft. For outside surfaces draft should be $\frac{1}{2}^\circ$ or more. For inside surfaces, it should be at least 1 to 3° .

Holes. Holes can be cored easily with good accuracy and finish. They should be perpendicular to the mold-parting plane to avoid the need for extra core pieces. Holes less than 13 mm ($\frac{1}{2}$ in) in diameter are generally more economically drilled. Drill spots are accurate and can eliminate jigs.

Machining Allowance. Stock allowances for machining should be 0.8 mm (0.030 in). On small parts the machining allowance may be less than 0.8 mm for holes and broaching.

Figure 5.2.9 illustrates the preceding recommendations.

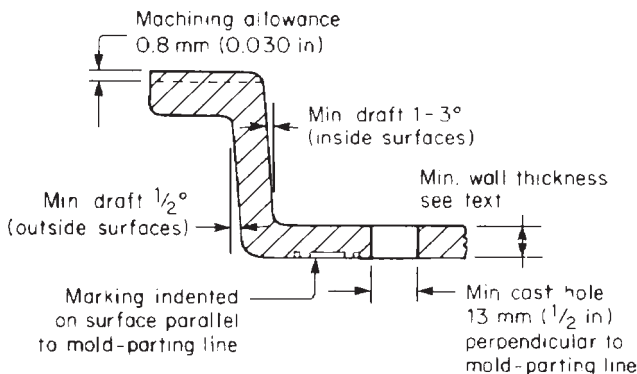


FIGURE 5.2.9 Design recommendations for plaster-mold castings.

Recommended Tolerances

Table 5.2.4 lists recommended dimensional tolerances for small plaster-mold castings.

TABLE 5.2.4 Recommended Tolerances for Plaster-Mold Castings

	Tolerance
Dimensions wholly in one-half of the mold	0.05 mm/cm (0.005 in/in)
Dimensions across mold-parting line	0.10 mm/cm (0.010 in/in)
Dimensions subject to horizontal shift between cope and drag of mold	0.10 mm/cm (0.010 in/in)
Flatness	0.05 mm/cm (0.005 in/in) in any direction
Surface finish	0.8–1.3 μm (30–50 μin)

CERAMIC-MOLD CASTINGS

The Process

Ceramic-mold casting is frequently referred to as *cope-and-drag investment casting*. The major distinction between ceramic-mold casting and investment casting is that the former relies on precision-machined metal patterns rather than the expendable wax patterns used in conventional investment casting. Ceramic-mold casting is similar to plaster-mold casting except that the mold materials are more refractory, require higher preheat, and are suitable for most castable alloys, particularly ferrous alloys. The refractory slurry consists of fine-grained zircon and calcined high-alumina mullites or, in some cases, fused silica.

In ceramic-mold casting, a thick slurry of the mold material is poured over the reusable split and gated metal pattern, which is usually mounted on a match plate. A flask on the match plate contains the slurry, which gels before setting completely. The mold is removed during the time when the gel is firm to prevent bonding to the pattern.

The Shaw process and the Unicast process are two proprietary variations of the ceramic-mold casting method. Before pouring, the molds are usually preheated in a furnace to reduce the temperature difference between the mold and the molten metal and to maximize the permeability available through the microcracked mold structure.

Typical Applications

Ceramic-mold casting has particular application in the casting of ferrous and other high-melting-temperature alloys in which the geometry is complex. Parts as heavy as 700 kg (1500 lb) are feasible. Even on such large castings the process has excellent accuracy and reproducibility. Fine detail and smooth surfaces are feasible.

Typical products cast by this process include stainless steel and bronze pump parts such as impellers and impeller cores, molds for plastic molded components, core boxes of cast iron, beryllium copper molds for the blow molding of thermoplastic resins, tool-steel molds for the molding of rubber components, tool-steel milling cutters, and press-working dies and die-casting dies of H-13 steel.

Economic Production Quantities

For complex parts, this process can be advantageous when the production quantity is as small as only one part. Savings are found in the machining that is eliminated. The process may be economic at higher production levels for parts that are too large to be advantageously investment cast but which require the desirable characteristics of investment castings: complex shape, dimensional accuracy, the use of alloys with a high melting temperature.

General Design Considerations

In this process, mechanical properties suffer the loss of the chill effect because the mold materials are such good insulators that a coarse-grained structure results. The designer can compensate for such a reduction in strength by making critically stressed

sections somewhat heavier, or the metallurgist can add grain refiners to the molten metal before pouring. Areas subjected to major stress can be chilled by incorporating suitable chills in the mold.

Design considerations and recommendations that apply to plaster casting also apply to ceramic-mold casting.

Suitable Materials

Most castable materials can be ceramic-mold cast. Typical materials include stainless steel, bronze, beryllium copper, gray iron, and tool steel.

Recommended Tolerances

An as-cast surface finish of $3\text{ }\mu\text{m}$ ($120\text{ }\mu\text{in}$) or better can readily be achieved. Dimensional tolerances are $\pm 0.1\text{ mm}$ (0.004 in) for the first 25 mm (1 in), with incremental tolerances of $\pm 0.025\text{ mm/cm}$ (0.0025 in/in) for larger dimensions. Across the parting line, an additional tolerance of $\pm 0.3\text{ mm}$ (0.012 in) should be provided.

OTHER CASTINGS